Docket No. 2003-120-TAP

VARIABLE CURVATURE IN TAPE GUIDE ROLLERS

RELATED APPLICATIONS

The present invention is related to commonly assigned and co-pending U.S. Patent Application, Serial No. 10/746,383, Attorney Docket No. 2003-075-TAP, entitled "REDUCING TAPE MEDIA DAMAGE IN DATA REGIONS", filed on 12/26/03 and hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to mitigating tape media damage. More particularly, the present invention relates to an apparatus for restoring tape media to the center of a tape guide roller.

2. Background of the Invention:

Magnetic tape media, including reel and cassette-style cartridges and other devices that use magnetic media, are used in many industries to store data, programs, and other information. Magnetic tape media is typically stored on reels or spools, which are cylinders about which the tape media is wound, typically having flanges to guide the tape media onto the cylinder. The spools may be housed in a cassette or cartridge to protect the tape and increase the ease of handling. Accessing information from a reel or spool of tape media typically requires that the spool be inserted into a

reading machine, which unwinds the tape media from the file spool, through a plurality of tape guide rollers and a read/write head and winds it onto a temporary storage spool (also referred to as a machine reel or machine spool) until the portion of the tape media with the desired information is reached. The temporary storage spool may either be external to the cassette (single reel) or integrated into the cassette (double reel). A magnetic read element reads the information, and, for the single reel cassette, the tape media is rewound back onto the original file spool and removed from the reader. For the double reel cassette, the tape is often parked halfway between the ends of the tape before being removed.

On a typical machine that is reading magnetic tape media, the tape guide rollers that control the tape media path have hard stops on each side of the roller. The spacing between the hard stops of the tape guide rollers is wider than the nominal width of the tape media. As the tape media is fed onto these tape guide rollers with hard stops, lateral tape media motion may occur during a start or stop operation, and edge damage may result. If the edge damage is severe, track following capability may be lost and the head to tape media spacing may increase to the point where data cannot be read back. In the most severe case the tape can break, leading to catastrophic failure.

As the thickness of tape media continues to get thinner, the tape media will be more prone to edge damage. A solution to lessen tape media damage would be

to eliminate the occurrence of the tape media wearing against the hard stops of the tape guide roller. One such technique includes using tape guide rollers that are continuously curved and exerts a force to the tape media during a lateral shift, which returns the tape media to a properly aligned position, thereby minimizing the potential for tape media edge damage. However, due to the continuously curved roller, the tape media is under constant tension or compression, which can lead to edge damage.

Thus, it would be advantageous to have an apparatus for controlling the position of a magnetic tape media within a reading machine to mitigate tape media edge damage.

SUMMARY OF THE INVENTION

The present invention recognizes the disadvantages of the prior art and provides an apparatus for reducing tape media edge damage in data regions and controlling the position of the tape media in a passive manner. The apparatus of the present invention controls where edge damage may occur by returning the tape media to a properly aligned position by using tape guide rollers with curved edge stops that exert a force to the tape media during a lateral shift.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a top view of a double reel tape cartridge in accordance with a preferred embodiment of the present invention;

Figure 2 is a top view of a single reel tape cartridge in accordance with a preferred embodiment of the present invention;

Figure 3 is a cross-sectional view of a known tape guide roller that uses hard stops to control the tape path;

Figure 4 is a cross-sectional view of a tape guide roller showing the tape centered and experiencing substantially zero restoring force in accordance with a preferred embodiment of the present invention;

Figure 5 is a cross-sectional view of a tape guide roller showing the tape offset and experiencing a restoring force in accordance with a preferred embodiment of the present invention;

Figure 6 is a cross-sectional view of a tape guide roller showing varying amounts of possible curvatures in accordance with a preferred embodiment of the present invention;

Figures 7A and **7B** depict another embodiment of the present invention in which two tape guide rollers may be used in opposition to one another to control the path of the tape media; and

Figures 8A and **8B** depict another embodiment of the present invention in which two tape guide rollers may be used in opposition to one another to control the path of the tape media, with one tape guide roller taking advantage of a hard stop.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to **Figure 1**, a top view of a tape cartridge is depicted in accordance with the present invention. Tape cartridge **100** includes file reel **102** for supplying tape media to machine reel **104**. File reel **102** is also referred to as a supply reel. Machine reel **104** is also referred to as a take-up reel. Tape media **106** travels in a tape media path between file reel **102** and machine reel **104**. Alternatively, multiple read/write heads **108** may be used for reading and writing data to tape media **106**.

In this example, a plurality of tape guide rollers **112**, **114**, **116**, **118**, and **124** are provided for guiding tape media **106** through the tape media path, although any number of tape guide rollers may be used in the tape cartridge. Each tape guide roller **112**, **114**, **116**, **118**, and **124** has a hollow core (not shown), which slides over a roller guide on the tape cartridge. The tape guide rollers may be flanged or unflanged, spinning or stationary, contoured or not contoured. Tape guide rollers **112**, **114**, **116**, **118**, and **124** limit lateral tape media motion, skew, and cross-web tension.

Post guides **120** and **122** may also be used to extend the total length of the tape media path. The inclusion of post guides **120** and **122** in tape cartridge **100** permits tape guide rollers **112**, **114**, **116**, **118**, and **124** to be moved as far as possible from file reel **102** and machine reel **104**. Any known guides may be used to implement post

guides **120** and **122**. Post guides **120** and **122** may be flanged or unflanged, spinning or stationary, contoured or not contoured.

Tape cartridge **100** is typically housed within a housing in a storage device. The housing, such as housing **110**, is a finite size and a particular shape as determined by marketing requirements. The size and shape of the housing limits the placement of the various rollers, guides, heads, and reels of the tape mechanism.

Edge damage may occur in file reel **102** and machine reel **104**. Edge damage may occur when the tape drive performs a start or stop operation. When the tape media is started again or is stopped, the tape media may experience some lateral motion as the tape media is brought up to speed or when the tape media is stopped. On a typical spool holding the magnetic tape media, the spacing between the upper and lower flexible flanges of the spools (both the file spool and the machine spool) is wider than the nominal width of the tape media. As the tape media is fed onto these spools, the tape media may move in a perpendicular to normal tape media motion during a start or stop operation, resulting in edge damage. This perpendicular movement is referred to as lateral tape motion. Tape media edge damage may be caused when the flexible flange is forced against the tape media during shipment or rough handling, since the edge of tape media is standing out from the tape pack. Tape media edge damage may also occur on the various rollers and guides such as tape guide rollers **112**, **114**, **116**, **118**, **120**, **122**, and **124**. Tape damage occurs when

these rollers and guides use a hard stop on either one or both ends. As the edge of the tape media is in contact with the hard stop, the edge may undergo damage from scraping along the edge. If the edge damage is severe, track following capability may be lost and the head to tape spacing may increase to the point where data cannot be read back.

The present invention may also be used with single reel cartridges, such as cartridge **200** as shown in **Figure 2**. **Figure 2** illustrates a top view of a single reel tape cartridge in accordance with the present invention. Tape cartridge **200** includes file reel **202** for supplying tape media to a machine reel **218** located external to cartridge **200**. Tape guide rollers **204**, **206**, **208** and **210** guide the tape onto and off of file reel **202**. Tape guide rollers **212**, **214** and **216** control the tape past the reader/writer **220** and onto the machine reel **218**. Tape damage may occur in file reel **202** and machine reel **218** if the tape were to wear against the sides of the reels. Tape damage may also occur on tape guide rollers **204**, **206**, **208**, **210**, **212**, **214**, and **216** as tape media **222** travels in a tape media path between file reel **202** around tape guide rollers **204**, **206**, **208**, **210**, **212**, **214**, and **216** to machine reel **218**.

Figure 3 is a cross-sectional view of a known tape guide roller that uses hard stops to control the tape media path. Tape media **302** travels across tape guide roller **300** in an area of substantially zero curvature **304**. During times when tape media **302** experiences lateral shift, the tape media **302** wears against hard stops **306**, which prevents the tape media **302** from moving off the

roller. However, there is no correction added to the tape media **302** to restore it to an optimal position, thus increasing the risk of edge damage as the tape wears against hard stops **306**.

The present invention provides a method for preserving data integrity by reducing tape media edge damage in the tape data regions. Tape media is typically wound on one or two reels and around a plurality of tape guide rollers in a protective housing, such as a cassette or cartridge. Tape guide rollers act as guides for the tape media as the tape media winds to and from the reels and through read/write heads of a tape cartridge. As the tape media moves across the tape guide rollers, hard stops are provided at the edge of the tape guide rollers so that the tape media does not move off the tape guide roller. Tape media edge damage may be caused when the tape media wears against the hard stops. The present invention controls the tape media path as it moves with respect to the tape guide roller, such that the tape media is guided to a center portion of the tape guide roller, thus reducing tape media edge wear, preserving the integrity of the tape media and increasing the useful lifetime of the tape media.

Turning next to **Figure 4**, a diagram of a cross-sectional view of a tape guide roller showing the tape centered and experiencing substantially zero restoring force is depicted in accordance with a preferred embodiment of the present invention. Tape guide roller **400** is shown having equal areas of positive curvature **404**, and an area of substantially zero curvature **406**. Tape

media **402** travels across tape guide roller **400** in an optimal position being in the area of substantially zero curvature **406**. As the tape travels across tape guide roller **400** in this optimal position the tape media **402** will experience substantially zero restoring force from the areas of positive curvature **404**. The restoring force experienced by the tape media is related to the mechanical properties of the media. As tape media **402** moves laterally into an area of positive curvature **404**, the tape media **402** must stretch if it is to stay in contact with tape guide roller **400**. This elongation generates a strain in the tape media **402** and creates a restoring force to return the media to its original shape. This restoring force is proportional to the wrap angle of the tape media **402** around the tape guide roller **400**. The larger the wrap angle, the larger the restoring force.

Turning now to **Figure 5**, a diagram of a cross-sectional view of a tape guide roller showing the tape offset and experiencing a restoring force is depicted in accordance with a preferred embodiment of the present invention. Tape guide roller **500** is shown having equal areas of positive curvature **504** and an area of substantially zero curvature **506**. As an example, as the tape media **502** travels across tape guide roller **500** and experiences lateral shift, the tape media **502** enters an area of positive curvature **504**. As the tape media **502** moves further up the positively curved portion of the tape guide roller **500**, the slope increases which increases the restoring force **508** applied to the tape media **502**. This restoring force **508** is exerted on the tape media **502** to

restore the tape media **502** to an optimal position in the area of substantially zero curvature **506**. The restoring force **508** exerted on the tape media **502** as it moves into an area of positive curvature **504** arises from both the increased stress due to the curvature in the tape guide roller **500** as well as the wrap angle of the tape media on the roller.

Figure 6 is a cross-sectional view of a tape guide roller showing varying amounts of possible curvatures in accordance with a preferred embodiment of the present invention. Tape guide roller **600** is shown having an area of negative curvature **602**, an area of substantially zero curvature **604**, and an area of positive curvature **606**. When the tape media travels across the tape guide roller **600** in the area of substantially zero curvature **604**, substantially zero restoring force is present. When the tape media travels across the tape guide roller **600** in the area of positive curvature **606**, a restoring force is present to move the tape media back to the area of substantially zero curvature **604**. However, when the tape media moves onto the area of negative curvature **602**, a negative restoring force will move the tape farther from the area of substantially zero curvature **604**. This negative restoring force may be used to control the motion of the tape; however, if the tape media moves too far away from the area of substantially zero curvature **604**, then the tape might come off tape guide roller **600** altogether. In accordance with the preferred embodiment of the present invention the tape guide roller has a tape guide surface with cylindrical symmetry. The cylindrical

symmetry may be defined by a function, which may be one of a linear function and/or a nonlinear function. Various functions may be considered in creating the curvature of the tape guide surface. Possible functions may include without limitation exponential, brachistochrone, quadratic, cubic, or higher order simple polynomials.

In an alternate embodiment of the present invention, two tape guide rollers may be used in opposition to one another to minimize the tension waves that might arise from increased compression of the tape media as shown in a top view of **Figure 7A**. The tape media **700** may be threaded between two tape guide rollers where the curvature can be in opposition as with tape guide rollers **702** and **706**. In this embodiment, if tape media **700** were to experience a lateral shift into the area of positive curvature **704**, tape guide roller **706** would provide the restoring force necessary to move the tape back to an area of substantially zero curvature **710**. If an alternate lateral shift were to occur, moving tape media **700** into the area of positive curvature **708**, then tape guide roller **706** would provide the restoring force necessary to move the tape back to an area of substantially zero curvature **710**. **Figure 7B** provides a side view of the alternate embodiment of **Figure 7A**.

In still another alternate embodiment of the present invention, two tape guide rollers may be used in opposition to one another to minimize the tension waves that might arise from increased compression of the tape media with one tape guide roller taking advantage of a

hard stop, as shown in **Figure 8A**. The tape media **800** can be threaded between two tape guide rollers where the curvature can be in opposition as with tape guide rollers **802** and **806**. In this embodiment, if tape media **800** were to experience a lateral shift into the area of positive curvature **804**, tape guide roller **806** would provide the restoring force necessary to move the tape back to an area of substantially zero curvature **810**. In addition, if the lateral shift experienced by tape media **800** was an extreme shift, then hard stop **812** would prevent tape media **800** from experiencing and further lateral shift. If an alternate lateral shift were to occur, moving tape media **800** into the area of positive curvature **808**, then tape guide roller **806** would provide the restoring force necessary to move the tape back to an area of substantially zero curvature **810**. **Figure 8B** provides a side view of the alternate embodiment of **Figure 8A**.

Thus, the present invention solves the problems associated with the prior art by providing an apparatus for reducing tape media edge damage. The apparatus of the present invention reduces tape media edge damage on tape media by restoring the tape media to an optimal position on the tape guide roller, which is aligned with the read/write head, machine reel, and/or file reel. Although tape media edge damage may occur, the present invention controls the position of the tape media, such that tape media edge damage is reduced, degradation to tape media integrity is reduced and useful lifetime of the tape media is expanded. As a result, data integrity may be preserved. In addition, the rollers act to

control the tape media path in a passive manner by returning the media to the substantially zero curvature part of the tape guide roller.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.